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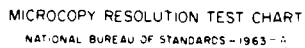
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TECHNICAL REPORT ARPAD-TR-84006

ELECTRO-OPTICAL CAVITY INSPECTION SYSTEM

HERBERT R. WOLTER

AUGUST 1984



U.S. ARMY ARMAMENT RESEARCH AND DEVELOPMENT CENTER
PRODUCT ASSURANCE DIRECTORATE

DOVER, NEW JERSEY

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This is an automatic inspection system that checks the interior surface of artillery projectiles for defects. A TV camera and wide angle lens on a probe obtain a video image which is processed in electronic logic for an automatic "Accept"/"Reject" decision. A TV monitor is also available permitting an operator to view the picture. The ARRADCOM effort was to determine the system's ability to detect real defects using good and bad shells. After all adjustments were optimized, a problem surfaced, namely continuous "Reject" signals which (cont)		

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20. ABSTRACT (cont)

rejected all shells whether good or bad. It was determined unfeasible to correct the problem due to costs and time required and the obsolescence of the opto-electronic sub-system. The project was therefore terminated.

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INTRODUCTION

This report covers the development of an automated system to inspect the surface condition of the internal cavity of artillery projectile bodies. Defects being sought are scale, fins, burrs, embedded material, draw marks, pits, or sharp protrusions. The image is obtained from a television/optical system and processed in electronic logic where an automatic "Accept"/"Reject" decision is made. This system was designed to handle the 155-mm M107 and the 105-mm M1 projectiles.

Frankford Arsenal Effort

This program was begun at Frankford Arsenal in 1969. It utilized a manual shell-handling system. A standard television (TV) camera with a wide angle lens on a probe obtained the interior image. The image was analyzed in electronic logic circuitry which was a modified off the shelf, intrusion-detection system. The electronic system in use today is the original system except for the TV camera which was replaced by a solid-state unit in 1977.

Contractor Effort

A contract was given to Innovation Associates in March 1977 for an automatic shell-handling system. The TV and electronic equipment were provided to the contractor as government-furnished equipment. The automatic shell handling equipment was satisfactorily completed and in January 1980, a contract modification was awarded to the same company to improve the documentation on the electronics. Contract funds were expended before all tasks were completed, which resulted in an inconclusive acceptance test. The system was delivered to ARRADCOM in June 1981.

ARRADCOM Effort

In March 1982, funds were received to complete the following at ARRADCOM: set up system, optimize all electronic adjustments, and test system for proper accept/reject decisions on good and bad shells.

ELECTRO-OPTICAL CAVITY INSPECTION SYSTEM

The system is mounted on a steel and aluminum table 5 feet by 8 feet. All mechanical actions are accomplished with pneumatic cylinders. The main material-handling element is a circular turret. The shell to be inspected is pulled from the loading station (fig. 1) to the center of the turret, where it is clamped between vertical V-blocks. The turret rotates 90 degrees, counterclockwise, to

the inspection position (figs. 2 and 3). At this point a movable carriage carrying the TV camera, light source, lens tube, and wide angle lens moves the lens tube through the fuze hole to inspect the shell interior. Illumination of the interior is obtained from a group of fiber optic bundles surrounding the lens. The other end of the fiber optics, on the carriage table, receives light from an incandescent projection lamp. If a defect is detected, the carriage immediately stops and withdraws from the shell. The turret rotates 90 degrees clockwise, and the shell is pushed out to the "Reject" conveyor (fig. 4). If the shell is acceptable, the turret rotates 180 degrees clockwise from the inspect position and pushes the shell out to an "Accept" conveyor.

Major Assemblies

Turret

All shell handling is done on the turret. It consists of two circular steel blocks separated by spacers. A pneumatic cylinder, rod, and pawl mounted to the upper plate moves the shells into and out of the turret. The shell rests on V-blocks bolted to the lower plate. Precise positioning for the inspection cycle is done with vertical V-blocks and a pneumatic cylinder which clamps the shell between the V-blocks. The assembly rotates on a base plate by means of rack and ring gears. The turret is indexed and locked at its operating positions by a shot pin (fig. 5).

Carriage Mechanism

A pair of 2-inch-diameter steel rods are mounted to the table on V-rails to form a track. A carriage, equipped with 1-1/2-inch, Thompson dual roundway bearings and V-mounting blocks, is pneumatically driven on the steel tracks under automatic or manual control by drive signals from the operator's control panel. The carriage supports the TV camera (RCA-TC1005-01), borescope for manual viewing, controllable light source, light-directing fiber optics, and lens tube with wide angle lens. The optical system is protected from damage which could be caused by accidental contact with a shell by a microswitch at the lamp box end of the lens tube. If activated, the microswitch shuts down the entire system (figs. 6 and 7).

Light Source

The light source is a 500-watt, tungsten filament lamp operating at a maximum of 300 watts. It is housed in a lamp box with heat-absorbing and condenser lenses, and is optically coupled to light-directing fiber optic bundles. Light intensity is controlled by a circuit that samples the relative intensity of the video signal from the TV camera.

TV Monitor

Although the TV camera signal is processed automatically in the electronic logic section, a monitor is available for simultaneous viewing by an operator, if desired.

Electronics

The signal from the TV camera is processed in the electronics analog and logic section. An "Accept" or "Reject" signal is sent to the system power control circuitry which then functions the turret (fig. 8).

Operator's Control Panel

Attached to the work table is an operator's control panel. The major controls are power, emergency off, and automatic/manual operation. In the automatic mode, the presence of a shell at the loading station activates a micro-switch which starts the inspection cycle. In the manual mode, there are controls to select and function each operation of the inspection cycle (fig. 9).

Theory of Operation

Analog Section

The principle of operation upon which this system is based is that a defect--whether it be raised material or crack, pit, or other depression--will cause a shadow. This shadow will be in sharp contrast to the brightly illuminated, opposing side of the defect. Such sharp contrast signals cause maximum positive and negative voltage excursions in the video output. Furthermore, they will have the fastest rise-and-fall time in the video signal. They are separated from the rest of the video signal by a process called differentiation.

The signal now contains only pulses representing leading and trailing edges of a defect. The pulses are converted to logic levels (+5 V d.c.) and leading edge logic is separated to one circuit; trailing edge logic to a second circuit.

Logic Section

The main purpose of the logic circuits is to prevent a single false defect signal (such as due to a transient) from becoming a false "Reject" signal, thus improperly rejecting a good part. Each TV raster line is divided into 100

units by feeding each of the two logic signals to a 100-bit shift register. As the signal leaves the shift register output, it has been delayed by exactly one raster line and is compared to the next line presently leaving the camera. This real-time line is adjacent to the delayed line and if a real defect is present, it should result in a bit pattern that is almost identical for both raster lines (a small allowance is made for some time shift due to camera travel). The two lines are compared in an AND gate and if an output pulse results, it is considered a true defect signal and is passed on to the next logic circuit. The above circuitry is duplicated for the trailing edge logic.

At this point, the logic is routed to one of two different logic-processing circuits. The first one stores an entire frame (252 raster lines) in a 20,480-bit shift register, the output of which is compared to the real-time frame. If the defect logic patterns of both frames match, a leading edge defect pulse is generated. The trailing edge defect pulse is generated the same way in a duplicate circuit. If both leading and trailing edge defect pulses are present, a single defect logic pulse is generated.

The second logic processing circuit takes the output of the "line"-comparing circuits, stretches the leading and trailing edge pulses in time, and checks that the stretched pulses have some overlap in time. If they do, a single valid defect logic pulse is generated. The principle behind this circuit is that a valid defect is not greater than approximately 3/8 inch.

Until the wide-angle lens is within a few inches of the shell bottom, the image in that area is out of focus and therefore useless. An electronic blanking square is generated which prevents any signals from getting through until the probe is close enough to the bottom to produce a sharply-focused picture.

The valid defect pulse is now sent to the last logic-processing circuit. The output of this circuit, when in logic "1" state, will latch the shell-handling system into the "Reject" cycle; therefore, it is reset to the logic "0" state at the end of every TV picture frame. If a defect pulse occurs during the frame, the system immediately goes into the "Reject" cycle. If the inspection proceeds to the end of the inspection cycle without finding a defect, the turret logic system will eject the shell to the "Accept" station.

DISCUSSION OF ARRADCOM'S IN-HOUSE EFFORT

Purpose

The purpose of ARRADCOM's effort was to:

1. Set up the inspection system at ARRADCOM and make it operational.
2. Become familiar with and optimize all electronic adjustments in the system.

3. Test the system using rejectable and acceptable shells to determine the defect detecting ability and repeatability of the system.

Description of Adjustment and Checkout Procedure

The fiber optic illumination system was observed to be providing an uneven distribution of light. At the lamp end, the heat absorbing lenses were broken and the fiber optic termination was discolored. The lenses were replaced and the fiber optic termination was polished while it was in place, since removing it would have required a major dismantling of the machine.

To provide a consistent signal during the adjustment procedure, several black paper wedges, 5 inches long, 0 wide at one end and 3/8-inch wide at the other, were glued to the wall of a shell cavity.

Checkout then proceeded, starting with the TV camera. The camera's automatic gain control voltage (AGC) is a measure of the scene's illumination. The greater the illumination, the lower the AGC, which results in less noise and greater bandwidth and resolution in the video signal. The AGC voltage was at a maximum value, indicating a low level of illumination. The light level could not be improved due to the previously mentioned problems.

In the technique used in setting the adjustments, the oscilloscope sweep was triggered by the TV vertical sync pulse. This sweep was used as a delaying trigger for the main sweep. When the delay trigger time was varied, any single video raster line could be examined on the oscilloscope. In this way the video signal generated by the black wedge glued into the cavity could be selected and viewed on the scope. The second trace on the scope was then used to observe the effects of varying and optimizing the adjustments through the signal processing chain. All adjustments except the final one were successfully made.

Background on Final Adjustment Problem

The TV image of the projectile interior is a circle. Due to the light that bounces off the interior walls of the metal tube that holds the wide angle lens, the image circle is surrounded by another narrow circle of different brightness than the area inside it and outside it (fig. 10). Since the system works on the principle that a defect causes a sharp change in contrast, this narrow circle generates multiple false "Defect" signals (fig. 10). This problem apparently existed from the beginning since the final adjustment is labeled "Shell Edge Blanking." It is essentially an amplitude-discriminating circuit which rejects all video signals below the set level and accepts all above. Although it can be set to operate properly for one given set of conditions (painted, unpainted, changing light levels), as soon as the probe is moved or a different shell is tested, the false "Defect" signals return and the shell, good or bad, is rejected.

CONCLUSIONS

1. The project must be considered unsuccessful since in the "automatic" mode, the multiple false "Reject" signals would reject every shell, good or bad.
2. It is not practical to spend more time or money to correct the existing problems with this optical-electronic sub-system since it is obsolete and in poor condition. However, considering the great advances available in present state of the art opto-electronic systems, a new effort could prove worthwhile using the existing shell-handling mechanism.
3. Operation of the automatic shell-handling subsystem--taking about 40 seconds for the full inspection cycle--is completely satisfactory.

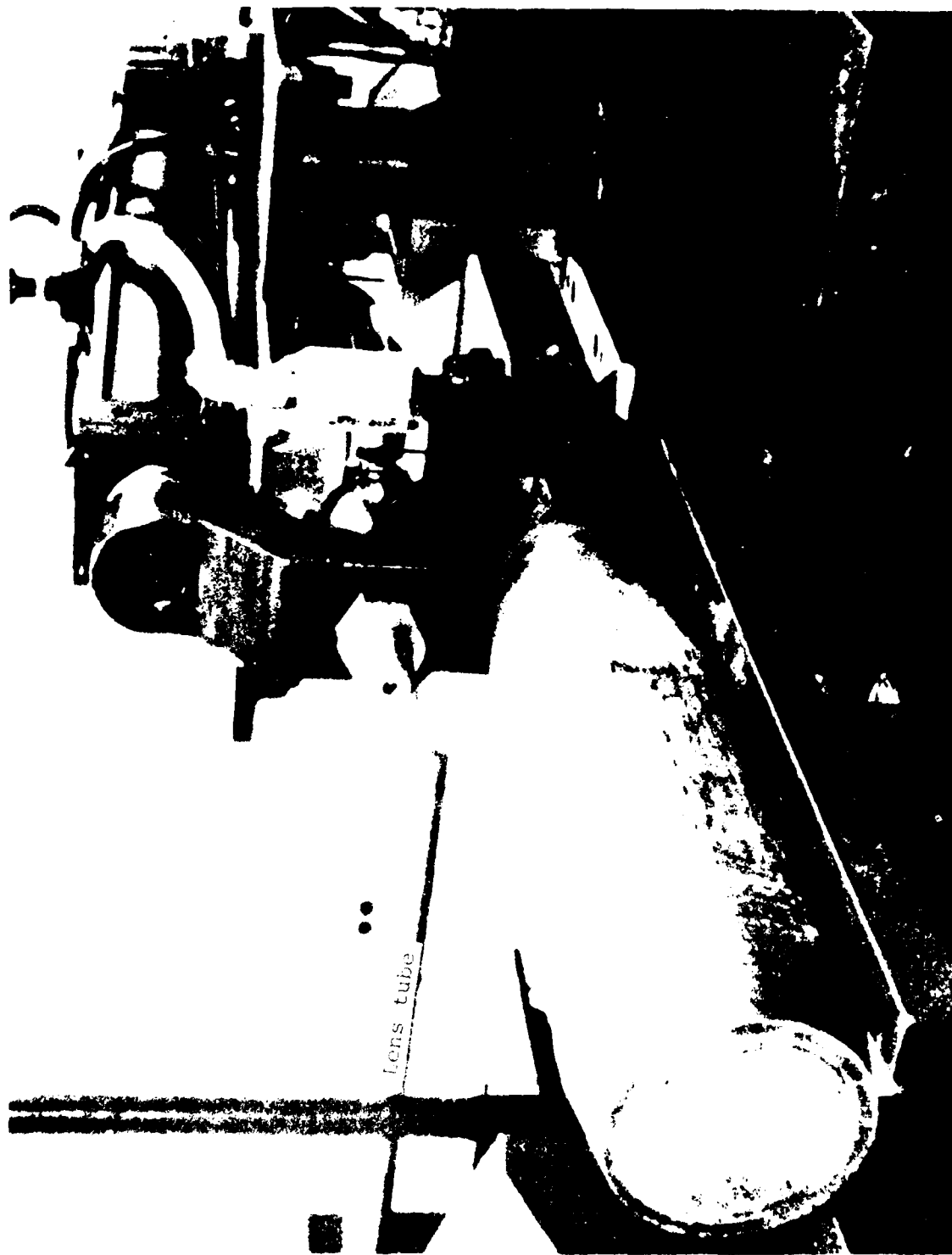


Figure 1. Cavity inspection system with left on loading station



Figure 1. Control system for the reactor position, from left to right:

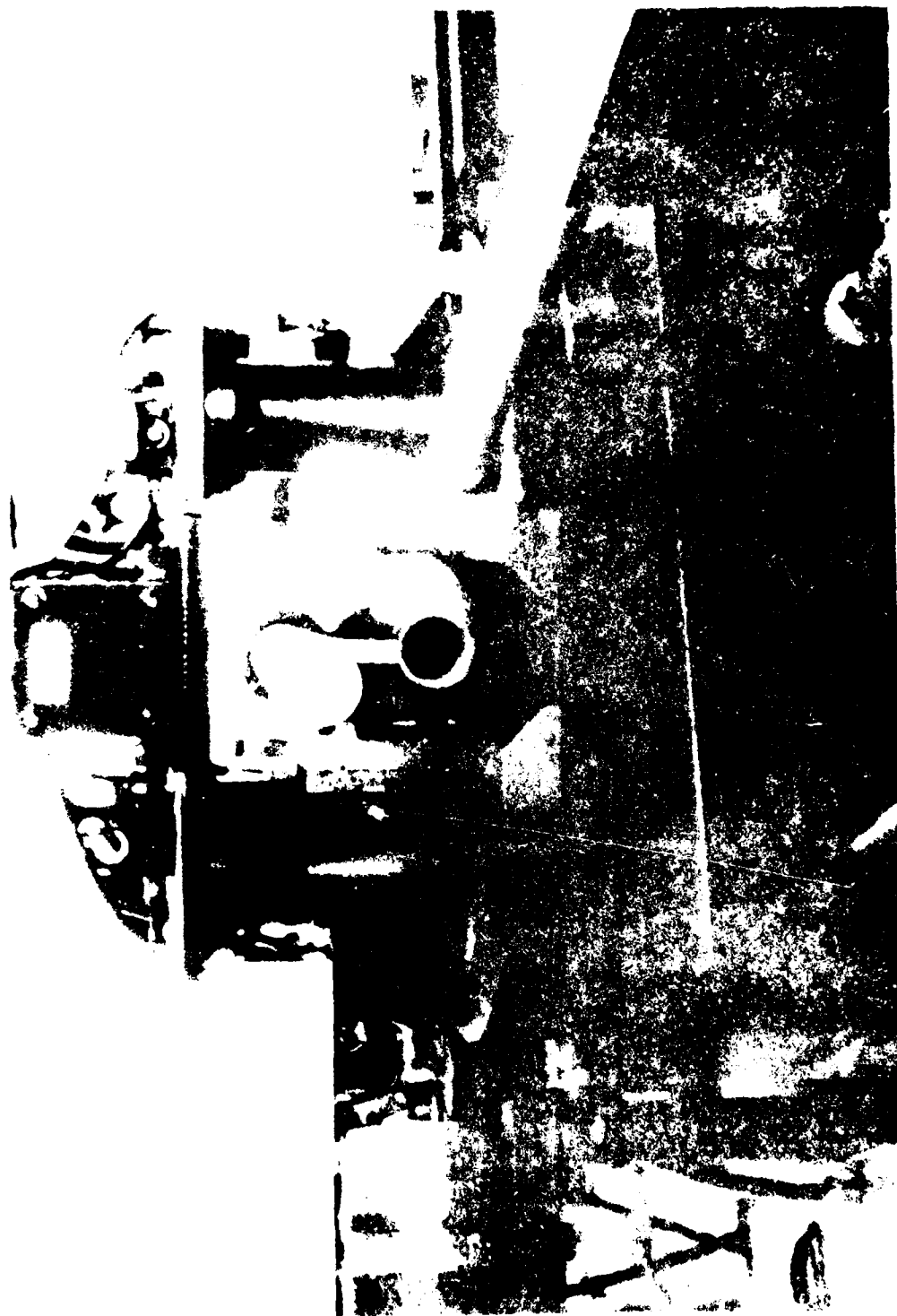


Figure 3. Turret approaching inspection position, ten tube on right

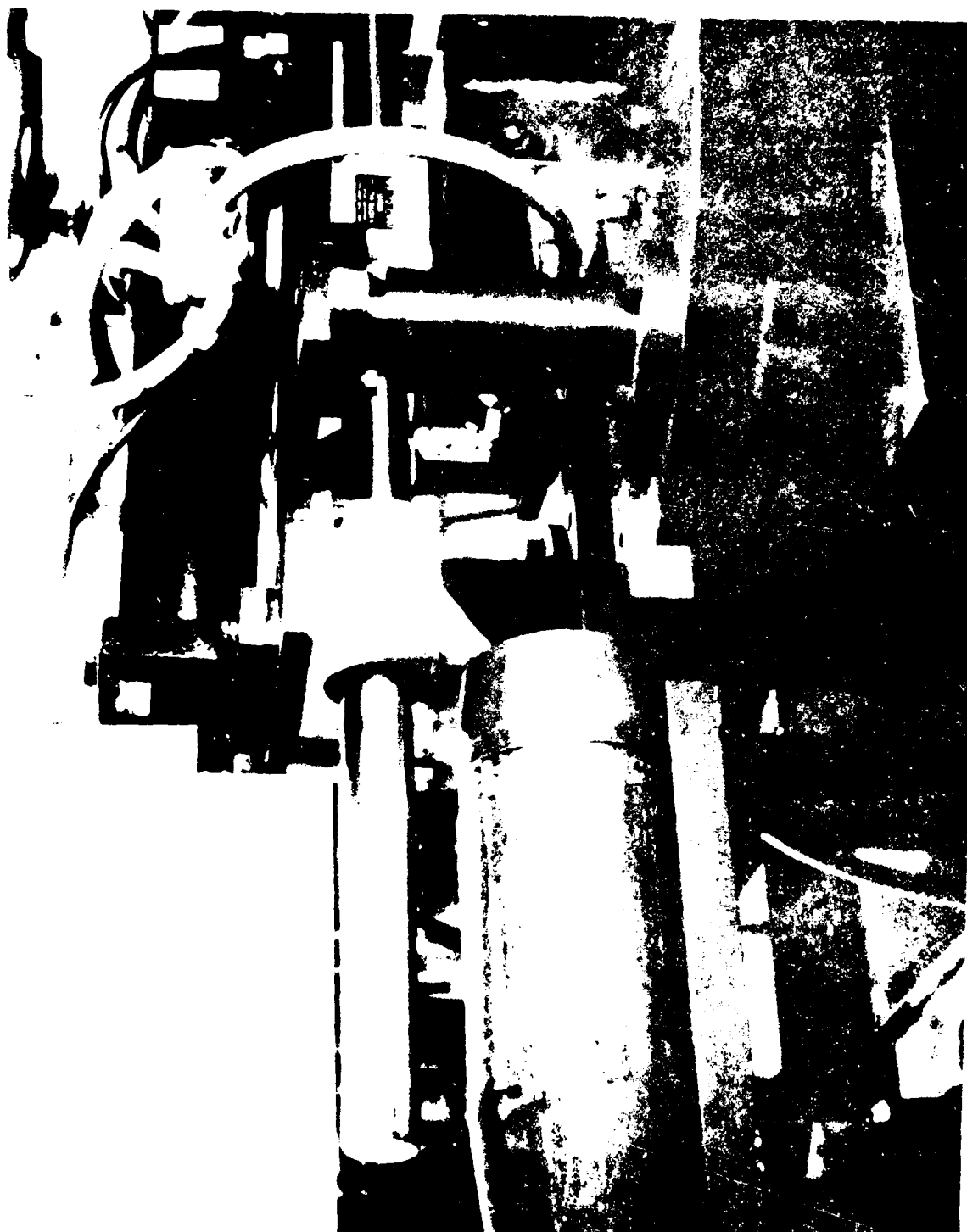


Figure 1. Bell on right. (10/10)

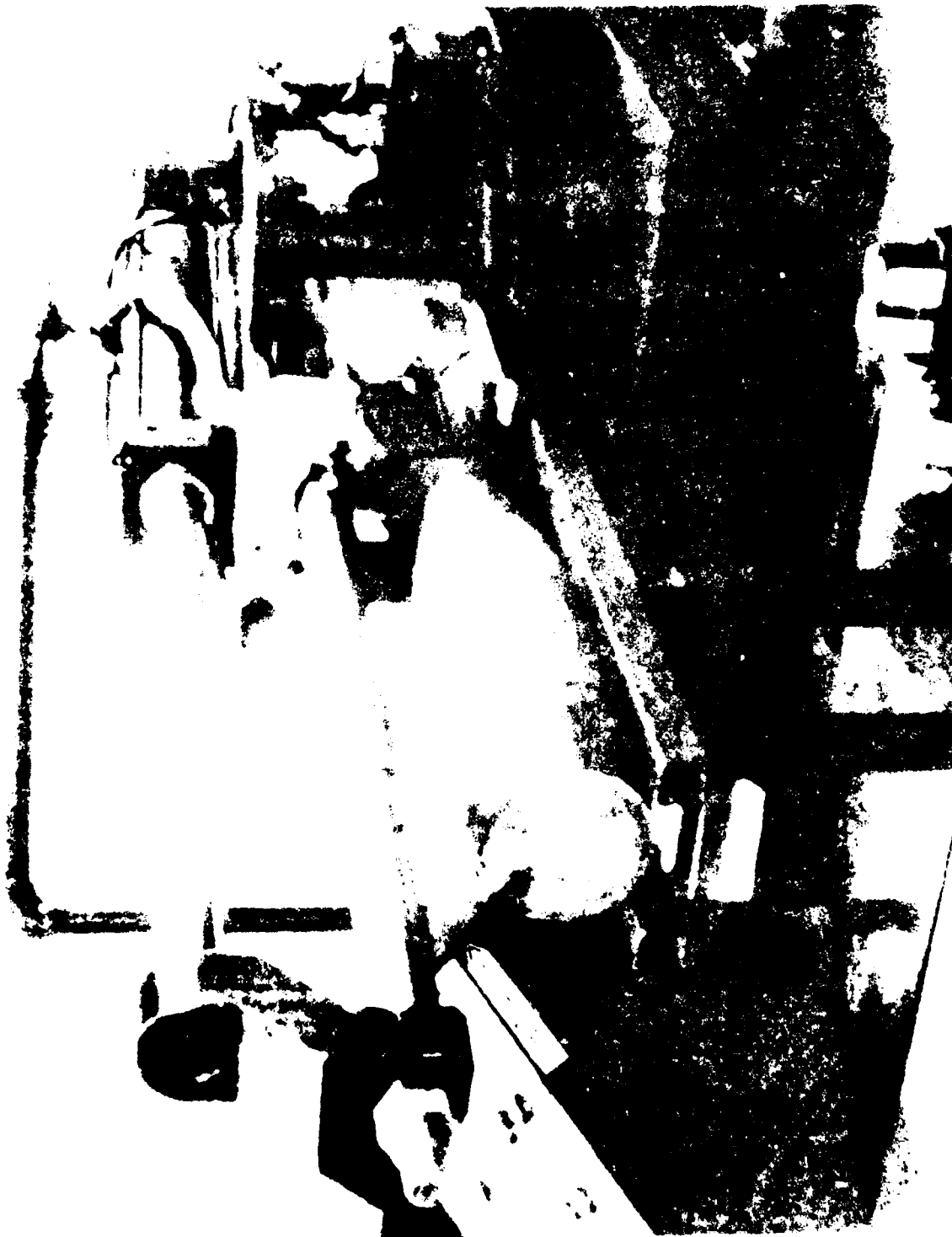


Figure 5. Turret with loading pawl extended



Figure 6. Correlation with ion tube to right of lamp box; foretopography, IV camera on left.

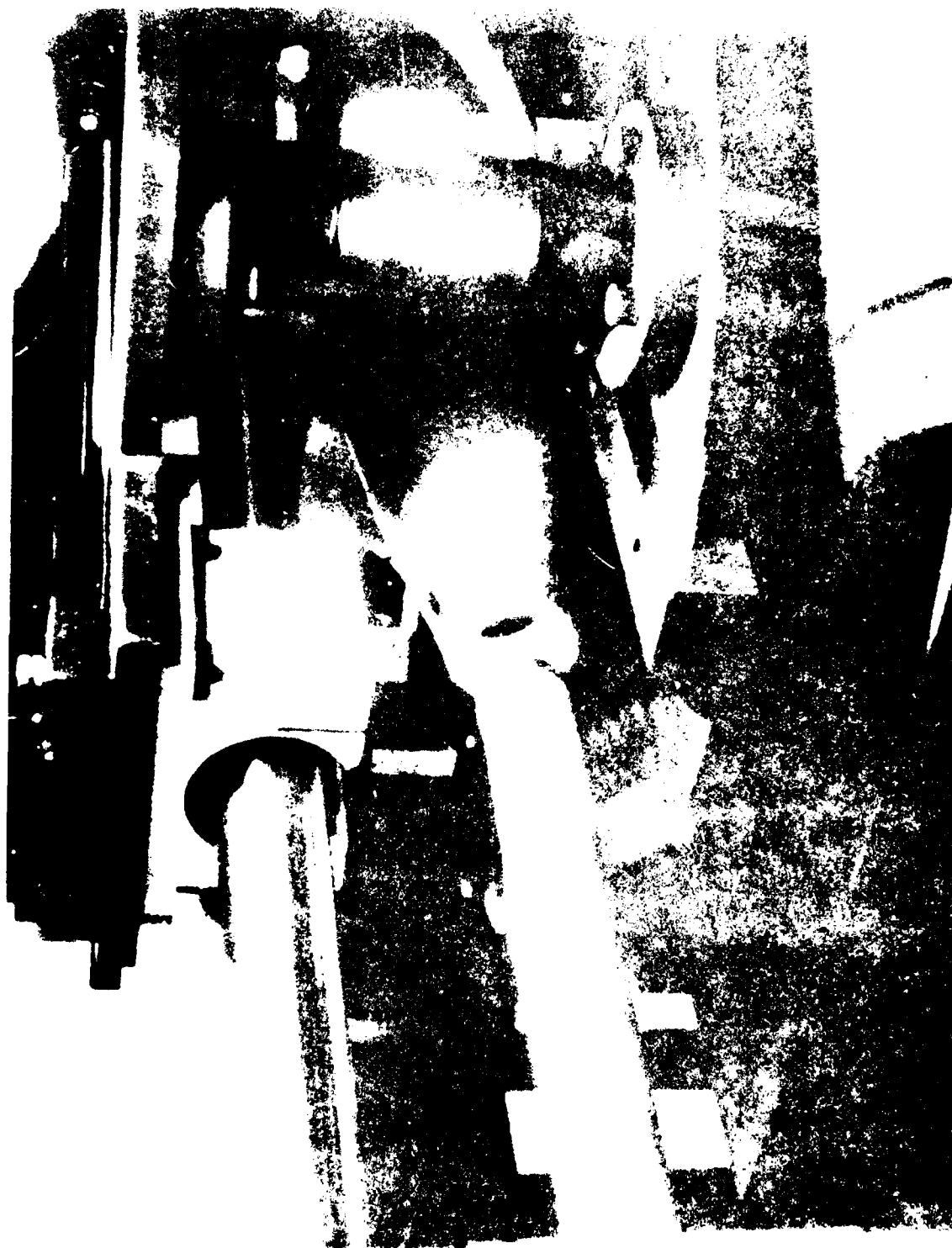
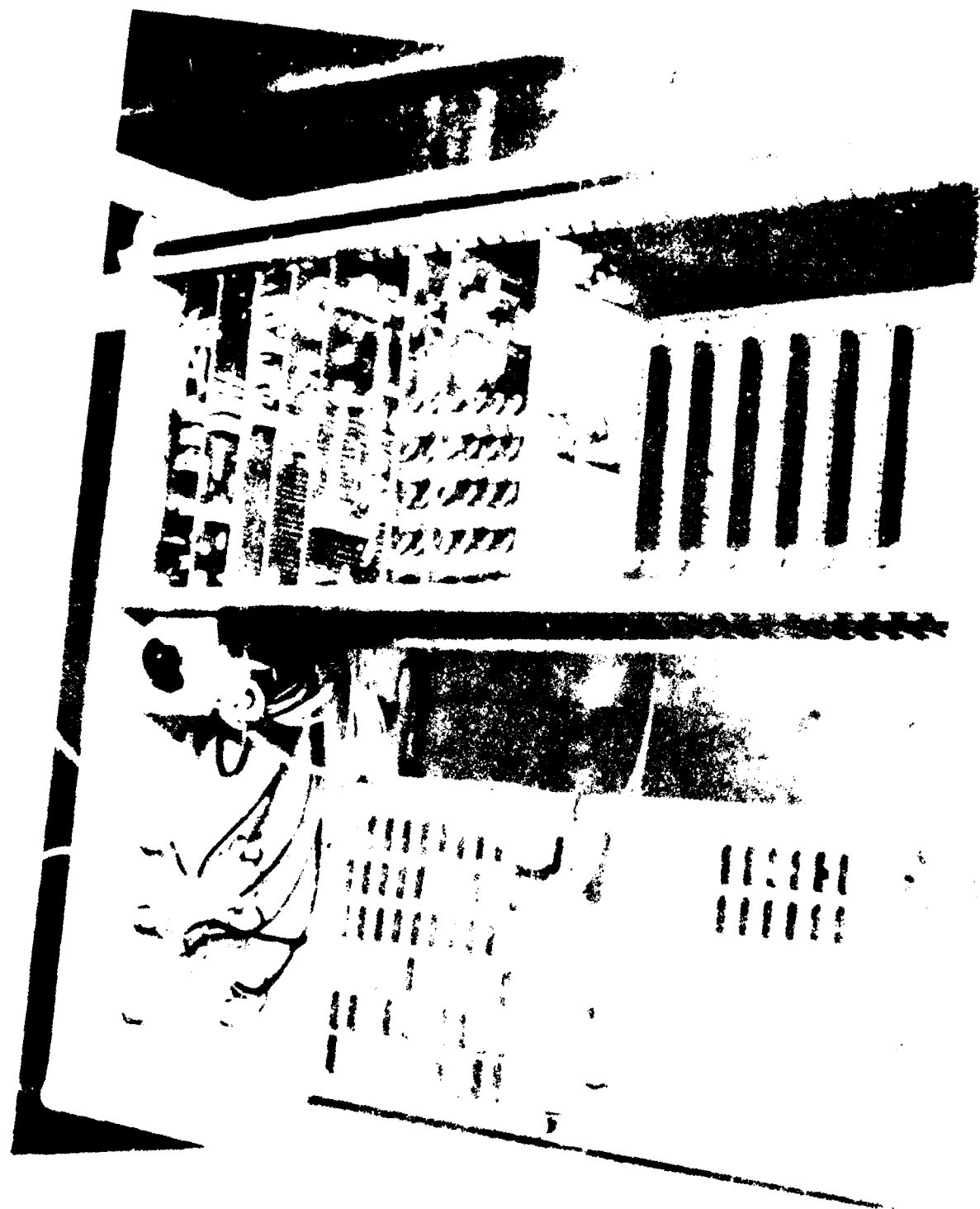


Figure 7. Lens tube entering projection cavity





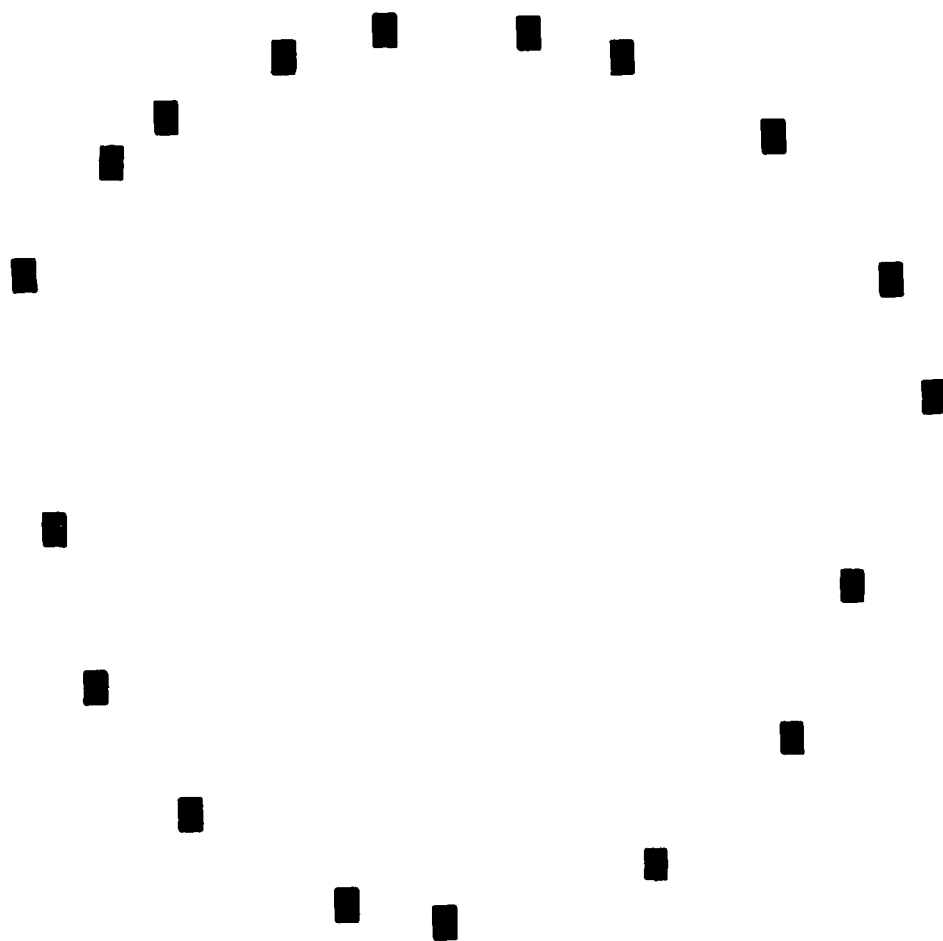


Figure 10. Simulated TV image showing contrasting ring and multiple false defect logir signals

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